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AGRICULTURAL EXPERIMENT STATION
PULLMAN, WASHINGTON

DIVISION OF HORTICULTURE

APPLE ROSETTE

By
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*In co-operation with the United States Department of Agriculture.
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APPLE ROSETTE

GENERAL STATEMENT

Apple rosette is a disorder that has appeared in the apple trees in nearly all sections of Washington, east of the Cascade Mountains. It is commonly recognized by the rosette of small leaves that appears on the end of twigs of the apple and pear trees. These twigs are usually barren of the side spurs and cluster of leaves common to the twigs of their age. The leaves of the rosette range in color from normal green to light yellowish green of solid color; or to leaves showing a mottle of dark green and light green or yellow. The twigs carrying rosettes during the summer usually fail to renew normal growth the following spring. Growth of the adjacent part of the tree is checked. The trouble may be confined to a small part of the tree, or appear on practically all twigs. If but few twigs are affected, little harm seems to be done. If many branches are involved, growth of the entire top is affected.

Trees seldom die quickly from this disorder, but are checked in growth and development so that they are often valueless. It is in this form that rosette has done most damage to the apple orchards of the Northwest.

DISORDERS SIMILAR TO APPLE ROSETTE

Smith (19) states that Peach Rosette is characterized by the tufts or rosettes of leaves that appear on the end of twigs or spurs throughout the tree top. It is destructive to the point of killing the trees, usually within three years. It is communicated from tree to tree by inoculations. Organic unions of wood give perfect distribution of the disease.

Smith (19) also describes peach yellows and states that prematurely ripened, red spotted fruits, and premature unfolding of leaf buds into slender pale shoots or into branched broom-like growths are the most characteristic symptoms of Peach Yellows. Trees seldom live more than four years after the first appearance of the disease in the branches. This disease is transmitted to healthy stock by budding and grafting.

Kelly and Thomas (10) describe the chlorotic condition of citrus trees as alkali injury. Floyd (5) reports a chlorosis disease of citrus trees in Florida and attributes the cause to an excess of moisture which has been added to the soil, and to the lack of humus. Smith and Smith (20) describe a similar condition in deciduous and citrus trees as a seasonal disease.

Bioletti and Bonnet (1) report a somewhat similar chlorosis disease of the grape vines in California and state that other plants are affected by what seems to be the same trouble.

Stringfellow (21) reports that chlorosis of vines and fruit trees may be cured by use of sulphate of iron dissolved in water and sprinkled about the roots of the trees. He believes that 5 to 10 pounds would cure a large bearing tree.

Orton and Rand (16) reported a chlorotic disorder of pecan trees in the southeastern part of the United States. They concluded that the cause was probably a lack of balance in the plant food materials in the soil or in some unfavorable physical condition and plant food material. McMurran (14) presented evidence to show that the pecan rosette is due to the soil conditions, and its prevalence can be reduced by fertilizing. In his work all the soils tested where the trouble appeared, gave acid or neutral chemical reactions. Rand (18) states that "The histological and cytological evidence suggests the pecan rosette in its specific sequence of signs and in the complexity of the structural and physiological derangement bears far more similarity to the known infectious chloroses than to those caused by soil or climatic conditions."

Dauthenay (4) states that the occurrence of chlorosis on fruit trees in calcareous soils is quite common wherever, for any reason, the nutritive elements of the soil become unassimilable to the tree. The use of sulphate of iron for preventing this disease gives partial relief and, according to the author, it acts upon the lime changing its form. This treatment alone is not sufficient but should be supplemented by the use of proper fertilizers.

Chlorotic plant diseases of pineapple, tobacco, potatoes, tomatoes, pears and other plants have appeared in various sections and have been reported. These, however, in their general character seem to bear very little, if any, relation to the type of trouble under discussion in this paper.

APPLE ROSETTE

Hilgard (8) in writing on the alkali injury to fruit trees describes briefly the characteristic rosette as it appears on the apple trees. He further states that the bark of the roots in the surface soil usually changes to a dark brown and the trees are practically girdled.

Loughridge (12) emphasized the effect of sodium chloride on the trees and gives illustrations of Dutchess and Jonathan apple trees showing very prominently the typical rosette formations. He gives also maximum alkali content of the soils in which good and poor growth was being made by different kinds of fruit trees.

Paddock (17) describes apple rosette and concludes that the trouble is due to uncongenial soil conditions and probably the presence of an excess of lime in the soil. Judson (9) reports apple rosette in Idaho, and states that attempts to propagate affected wood resulted in the disappearance of the disorder from new growth secured. Lowther (13) reports an extensive study of apple rosette, and concludes that the disorder or disease may be caused by any one of a list of unfavorable environments or a combination of them. Among the elements of environment found where this disorder is prevalent, are excessive water content of soil; high alkali content of soil; strata of hardpan near surface of soil; root rot; crown gall of the trees; extreme drought through the summer; low soil fertility.

Mix (15) states that drought seems to be directly responsible for drought spot or cork diseases in fruits and rosette or very similar condition in the apple trees in the orchards of the Champlain Valley of New York.

Brooks and Fisher (2) report upon the appearance of drought spots and related physiological diseases of the apple. Troubles identical with cork, or closely related thereto, are widely distributed and have been observed all over the Pacific Northwest, in the Champlain region of New York, and in the Virginias and supposedly also in Australia. The authors do not in this work, however, indicate any relationship between these diseases as they appear on the fruit and the appearance of apple rosette or chlorotic condition of the foliage.

Heald (7) states that apple rosette may be looked upon as a derangement of the nutrition. It is neither infectious nor contagious. There seems to be a close relation between rosette and certain types of winter injury.

Clawson (3) found that apple rosette was prevalent in the clean cultivated orchards in the Wenatchee District in 1916, but that it had practically disappeared from all orchards in which a legume cover crop had been growing for three consecutive years.

This disorder first became serious in the orchards of Washington about 1907, and increased in prevalence until about 1914. Many trees were destroyed, but most of the affected ones have improved to the point of complete recovery. The disease is still occasionally seen throughout the irrigated orchards of the Northwest.

GEOGRAPHICAL DISTRIBUTION

The apple rosette is most prevalent in the clean cultivated orchards of the Rocky Mountain and Cascade Mountain plateau areas. It has been reported as existing in the Champlain Valley of New York, in a few small areas in Virginia and West Virginia, and in Kingman County, Kansas. It appears to be very common in the orchards of

Fig. 1. Typically rosetted apple tree.

California, Utah, Wyoming, Montana, Idaho, Oregon, Colorado and Washington.

SYMPTOMS AND EFFECTS

Apple rosette is easily recognized by the rosette or dense cluster of small narrow yellowish leaves produced on the end of twigs which are void of normal leaves along the side. This rosette or cluster of leaves usually consists of a short twig from one-half to one and one-half inches in length, to which is attached as many leaves as a twig 18 inches long would commonly carry. The internodes are so short that the stem becomes almost a base or crown to which the leaves are attached. The disorder affects terminal growth first, and later spreads to all parts of the tree, as in Fig. 1. Strong terminal branches which are badly rosetted often have small side twigs that carry yellowish colored leaves which taper in size toward the tip of the branch, as in Fig. 3. These affected branches may appear scattered throughout the tree top or may be clustered on one side of the tree. The rosettes occasionally appear as short side branches attached to branches which beyond this point are making a vigorous and luxuriant growth. This condition indicates a return to normal growth which may be temporary or permanent.

The leaves of the rosette are narrow and slender in form. The blade of the leaf is yellowish green, and in many cases finally changes to yellow along the edge. The yellow area gradually spreads until the entire leaf may be changed. The rosette formation may be produced by the first growth of the early spring, as in Fig. 4, or may terminate and be a part of the growth of the season in which the twig has made normal development during most of the season, as in Fig. 5. The rosette developed late in the growing season is not prominent.

Rosetted twigs, in the beginning of the spring following the first appearance of the rosette that develops in late summer, often produce a number of short side spurs which are usually just long enough for the attachment of three or four leaves. Such twigs usually die at the end of the summer following the formation of the rosette spurs. These twigs usually have a greater diameter than the normal.

The diseased twigs sometimes develop approximately normal internodes with long narrow leaves which very generally show more or less pronounced chlorotic condition. These twigs and leaves seldom appear except in advanced stages of the disease. This form is illustrated in Fig. 6.

The rosette formation of the leaves which start from side buds and from the terminal buds is sometimes very prominent in the early spring. This form of the disorder is illustrated in Fig. 7. The leaves seldom

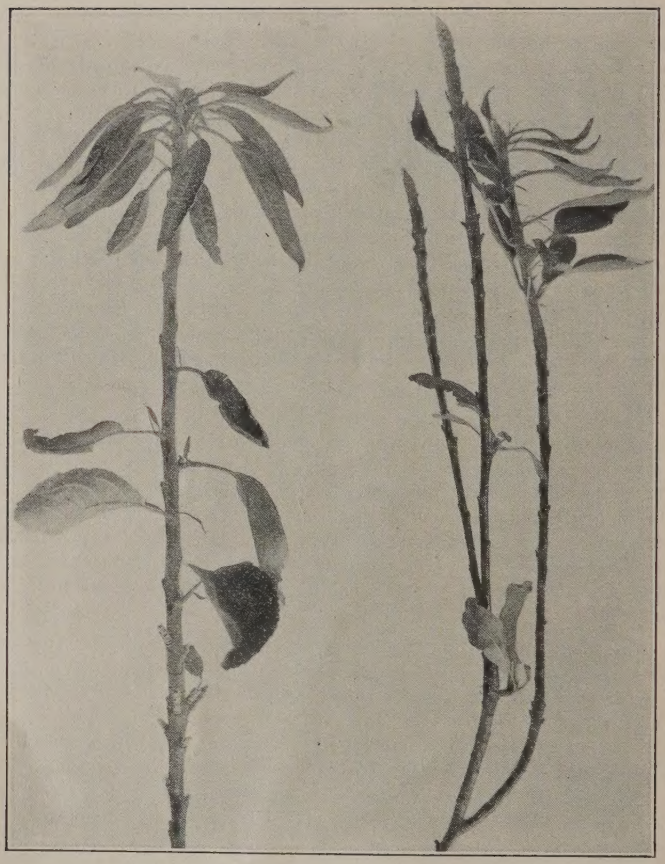

Fig. 2. Typically rosetted apple twigs. Note the small spurs or twigs developed on the side of the rosetted wood.

Fig. 3. A common type of twigs and foliage affected with rosette and chlorosis. This type of branch is commonly a short side branch connected with a larger branch which is rosetted. Note the slender leaves toward the bud end of the twig. The most slender leaves show but little dark green tissue. The edge of the leaf blade is distinctly yellow.

Fig. 4. The lower twig at the left shows a typical rosette of leaves as the first growth in the spring. The twig at the right shows a characteristic rosette and winter injured twig. In this twig the winter injury is but slight.

open sufficiently to develop into normal leaf shape, and commonly die by mid-summer. They give the twig the appearance of winter injured wood, hence the term "winter twig blight" or "winter injury."

These twigs will often remain green through the summer and die the following spring. The inner bark and cambium often show brownish spots and a slightly roughened or uneven effect in the surface of the bark. This stage of the disease is undoubtedly in part the result of unfavorable winter conditions, but it commonly appears on trees showing rosette development in other branches. It has been impossible clearly to classify or separate many of these cases and say which is the most influential causal factor, rosette or winter injury. It seems probable that both causes are active.

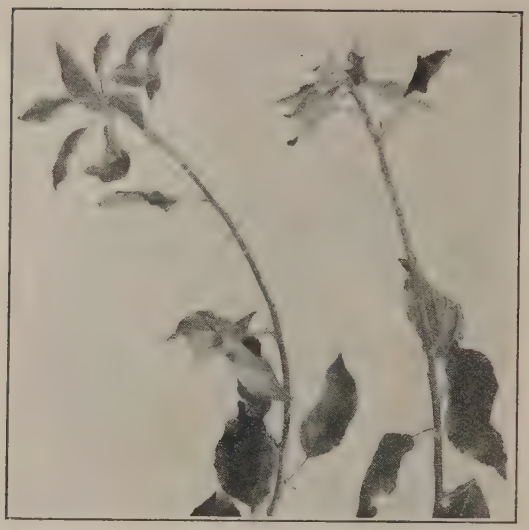

Fig. 5. Twigs that have made normal growth for most of the season and are terminated with a rosette of small leaves. This is a mild case of rosette.

Fig. 6. A small branch which was attached to a larger branch that was badly affected with rosette. In this twig the inter-nodes are practically normal in length. The leaves are slender and mottled yellow and green.

Fig. 7. A typical combination of winter injury and rosette as it appears in early spring. Extreme forms of this are shown in side twigs. The center branch is but slightly affected. This form of rosette is probably primarily caused by winter injury.

ETIOLOGY OR CAUSE

The rosette disease is evidently non-parasitic in its nature. No one has reported an organism connected with the trouble. Careful microscopic examinations and plate culture tests have failed to find any organism that could be considered a causal factor. Inoculations with needles, with transfer of buds, and with diseased wood and bark from affected wood to normal wood made in 1911, 1912 and 1914, in every case failed to produce the trouble in the normal wood. In 1912 and 1913, affected one-year-old twigs were used as scions in top grafting work. These were worked into apple trees which were making normal growth and were not in the affected area of the orchard. Only about 50 per cent of the affected scions grew and by the end of the season they had become normal in growth and continued normal in their development, as in Fig. 8. Affected trees have regained normal growth development in many orchards, and the formation of the rosette is still evident in the bark scars existing.

In the college orchard, rosette has been most prevalent in the trees growing on low ground where there is a slight seepage. It has appeared in a few cases on trees on higher land. In an orchard survey in the Yakima Valley covering some 60 orchards, the disorder was found more prevalent on the trees standing on lower ground where there was seepage or sub-irrigation sufficient to maintain a higher soil moisture and a higher alkali content of soil. In the irrigated orchards, the disease has appeared in orchards that received an abundance or even surplus of water, and in orchards that received less water than was needful for the development of the trees. The amount and frequency of irrigation does not seem to be a direct influence in modifying the prevalence of rosette.

A study of the roots of affected trees has been made in many orchards in irrigated districts and in the orchards of the State College at Pullman. Diseases like Crown Gall and Root Knot were found on many affected trees and as frequently on normal trees in each orchard. Collar Rot resulting from winter injury has been found as often on normal trees as on affected trees. Field Mice, Gophers and Moles have frequently injured trees but this has in no way modified development of rosette. Root pruning by frequent plowing and cultivation has been suggested as a possible cause. A study of the distribution of the roots in the soil of the clean cultivated orchards has not brought to light any indications of severe pruning as most of the plowing and cultivation done in such orchards has been too shallow to reach many roots. Also in many of the orchards in which alfalfa and clover crops have been grown the land has been thoroughly disked either in the late fall or early spring of each year and in some of these it has been disked once or twice during the summer. This mid-

Fig. 8. The scions used in making this top graft were badly rosetted at the time they were set. Normal growth was resumed during the first season after the graft was made and has continued for four years. The scars in the region of the spurs to which the apples are attached indicate the rosetted condition of the original scions.

summer disking practiced in working the alfalfa or cover crop into the soil has usually stirred the soil to a greater depth than is practiced in midsummer tillage in the clean cultivated orchards.

In digging and washing out small orchard trees that showed rosette, many trees have been found that had a poor root system but no root injury, disease, malformation, decay, disintegration of the roots nor peculiar distribution of the roots in the soil has been found to be a constant characteristic of rosetted trees.

NITRATE NITROGEN CONTENT OF SOIL

In order to secure information on the relation of the supply of nitrate nitrogen in the soil and the development of apple rosette, one block of the college orchard was selected for study in 1917. The trees were 8 and 9 years old, and were set in ground that had been in orchard about fourteen years before this lot of trees was planted. This land had been in clean tillage most of the time since 1896 and since 1912 had not received any fertilizer, manure or cover crop. Each year the land was plowed or disked about six inches deep in the early spring, and kept well cultivated the rest of the season. The land slopes to the southeast. The normal and rosetted trees were mixed as they stood in the orchard, but on the average the rosetted trees were on the lower ground. Rosetted and normal trees were selected in pairs, as No. 1 and No. 11; No. 2 and No. 12, were adjacent trees in the row.

Soil samples representing the first six feet of soil were collected on July 12, August 6, August 18, September 1, and September 15. In each case the sample of soil was taken within 12 feet of the trunk of the tree for which it was numbered. The nitrate nitrogen content was determined in parts per million of soil, and was found to vary greatly in the different samples. The data secured are presented in Table 1. These data are not conclusive, but seem to indicate clearly that the lack of nitrate nitrogen in the soil is not a controlling factor in the development of apple rosette.

Table 1. The nitrate nitrogen content in parts per million of the soil surrounding normal and rosetted trees in the college orchard.

Tree Condition	Tree No.	Jul. 24	Aug. 6	Aug. 18	Sep. 1	Sep. 15	Aver.
Normal	1	21.56	15.35	16.65	26.88	17.16	19.52
Normal	2	9.73	11.56	13.80	21.95	15.40	14.59
Normal	3	20.30	15.58	13.61	18.08	14.71	16.45
Normal	4	17.03	24.05	22.56	22.61	25.88	22.42
Normal	5	7.40	15.10	13.95	13.25	16.76	13.29
Normal	6	6.66	8.91	12.41	16.93	16.90	12.36
Normal	7	7.03	13.30	17.50	17.33	17.96	14.74
Normal	8	18.88	13.56	12.11	17.23	21.63	16.68
Normal	9	17.86	15.80	15.73	24.96	23.16	19.50
Normal	10	19.95	12.45	16.50	16.40	15.23	19.50
Average		14.64	14.61	15.50	19.66	18.46	16.50
Rosette	11	15.08	15.30	12.31	21.1	13.70	15.84
Rosette	12	20.16	23.93	25.15	32.	24.30	25.30
Rosette	13	11.66	23.30	30.65	31.68	30.03	25.45
Rosette	14	17.55	23.56	37.08	46.70	40.55	33.08
Rosette	15	19.53	15.73	19.70	22.81	28.36	21.22
Rosette	16	23.21	17.56	19.11	13.25	25.68	19.76
Rosette	17	11.00	14.96	8.13	9.71	6.81	10.12
Rosette	18	20.80	37.80	13.50	25.55	20.28	23.58
Rosette	19	20.75	16.85	14.30	21.86	8.11	16.35
Rosette	20	11.13	10.56	39.16	37.66	33.70	26.44
Average		17.15	19.95	21.90	26.23	23.18	21.61

INFLUENCE OF HUMUS AND SODIUM COMPOUNDS IN ORCHARD SOIL

In order to determine the relation of alkali to the apple rosette, soil samples were taken from orchards in Yakima and Wenatchee Valley in 1913 and 1914. The soil samples were taken from orchards, one section of which was in clean tillage, and the other section of the same general character of soil, that had been for three or more years growing a cover crop of clover or alfalfa. The soil samples were taken with a soil auger to a depth of two feet and represent the first two feet of soil. These samples were analysed for humus and volatile content, and for their total sodium bicarbonate content. No soil was found that was not alkaline and all soil samples were very low in humus. In every orchard in clean tillage, rosette was found on trees adjacent to the area from which the soil samples were taken. In the cover cropped orchards rosette had been approximately as prevalent as in the adjacent clean tilled orchard, and practically complete recovery existed in every case.

The prevalence of rosette or chlorotic foliage in the clean tilled orchards seems to bear no relation to the percentage of humus and volatile material, nor of bicarbonate of soda existing in the soil. The cover crop, according to the results presented in Tables 2 and 3, does not seem to have modified measurably either the humus and volatile content or the sodium bicarbonate content of the orchard soils. It was noticeable that the soil in the clean tilled orchards contained slightly more sodium bicarbonate in the top six inches than did the soils under cover crop.

Table 2. The sodium bicarbonate content of orchard soils of the Yakima Valley after various soil treatments

No. of orchards	Soil treatment	Avg. Pct. sodium bicarbonate	Max'm Pct. sodium bicarbonate	Min'm Pct. sodium bicarbonate
17	Clean tillage	.01	.034	.002
6	Alfalfa cover crop 3 years or more	.008	.024	.003
13	Red clover cover crop 3 years or more	.008	.018	.003

Table 3. The per cent of humus and volatile material in orchard soils of the Yakima Valley after various soil treatments

No. of orchards	Soil treatment	Avg. humus and volatile content	Max'm	Min'm
50	Clean tillage	3.86	5.03	2.09
22	Alfalfa cover crop 3 years or over	3.93	6.16	2.89
30	Red clover cover crop 3 years or over	3.86	4.98	2.69

INFLUENCE OF SODIUM COMPOUNDS ON SMALL TREES

The first attempt made by the department to develop rosette under controlled conditions was made in 1914. One-year-old Jonathan apple trees were set in specially prepared soil in benches in the green house. Bench No. 1 received field soil which had a very low humus content; to this soil was added bicarbonate of soda as follows:

Plot 1 check, no bicarbonate of soda.

Plot 2 received bicarbonate of soda equal to .01 per cent of the weight of the dry soil.

Plot 3 received bicarbonate of soda equal to .04 per cent of the weight of the dry soil.

Plot 4 received bicarbonate of soda equal to .1 per cent of the weight of the dry soil.

Plot 5 received bicarbonate of soda equal to .2 per cent of the weight of the dry soil.

Plot 6 received bicarbonate of soda equal to .4 per cent of the weight of the dry soil.

Bench No. 2 was filled with soil which had a humus content between 8 and 10 per cent. To this was added sodium bicarbonate as in bed No. 1. All plots were given enough water to keep the soil moist but not enough to leach away the bicarbonate of soda.

These trees were grown in a greenhouse exposed to an atmosphere which had a relative humidity between 45 per cent and 85 per

cent. The temperature ranged between 60 degrees and 105 degrees F. with an average of 10 degrees to 15 degrees above that existing in the orchard.

This work was continued with the same trees in the summers of 1915 and 1916. The trees exhibited great variability in individual growth in the second and third seasons. The trees in Plots 1 and 2 made a normal growth throughout the test and were normal in foliage and twig development. Trees in Plot 3 showed normal growth and development during seasons of 1914 and 1915, but late in the summer of 1916 the foliage became yellowish green and brittle. The trees, however, seem to be in a fair state of vigor at the close of the test. All the trees in Plot 3 made little growth in the summer of 1916 and developed yellowish brittle foliage early in the season. Trees in the Plots 4 and 5 during the summer of 1915 and through the summer of 1916 developed small yellowish green leaves that were very brittle. Trees in Plot 5 were in very poor condition and the roots were dark, but the bark was not softened at the close of the test. Trees in Plot 6 in beds both 1 and 2 died before the end of the growing season of 1914. The roots were black and the bark was so soft that it crumbled and fell off when the trees were lifted from the soil. The foliage, however, in none of the trees showed chlorosis, nor did the twigs in any respect show distinct apple rosette formations.

Two hundred and sixteen one-year-old apple trees were set in pots of prepared sand, and grown in the greenhouse through the summers of 1917 and 1918. This sand was washed practically free of all soil and humus material. The clean sand for each lot of trees was measured out and then treated with the nutritive solution, thoroughly mixed and with the trees placed in 12-inch pots on April 24, 1917. There were six trees in each lot.

Four different nutritive solutions were used. The formula here given indicates the ingredients and the quantity of each applied to each pot.

Nutritive solution No. 1.

Calcium biphosphate	6 gms.
Potassium sulphate	3 gms.
Calcium sulphate	16.5 gms.
Magnesium sulphate	.52 gms.
Sodium sulphate	.45 gms.
Magnesium carbonate	.53 gms.
Potassium nitrate	4.5 gms.

Nutritive solutions numbers 2, 3 and 4, were the same as number 1, except in the potassium nitrate content. Solution number 2 contained potassium nitrate .5 gms. Solution number 4 contained no potassium nitrate.

Sodium bicarbonate and sodium chloride were added in quantities, and per cents indicated in Table 4 to each tree in each lot. The salts were pulverized, and sprinkled on top of the sand in each pot and disappeared in the second or third watering.

The water content of the sand during the growing period of the trees ranged between 6 and 11 per cent. This gave an alkali concentration 50 to 125 per cent greater than would exist in applying the same quantity or per cent of salt to fine silt soil.

The pots were set in open benches in the greenhouse and were regularly watered with measured quantities, to be sure that the sand was kept moist but that no material was washed out. They were well exposed to light, and were in an atmosphere, the humidity of which ranged between 45 per cent and 85 per cent during the entire period. These trees were set out of doors during winter, and were given no protection. A few showed discolored wood as a result of winter injury, but the leaves produced the following spring were normal in all respects.

Table 4. The amount of nutritive solution, sodium bicarbonate and sodium chloride given each tree. There were six trees in each lot.

		Sodium Carbonate		Sodium Chloride	
Lot.No.	Solution No.	Amount Applied	Pct. of Soil	Amount Applied	Pct. of Soil
A	1	0			
B1	1	.9	.005		
B2	1	1.8	.01		
B3	1	3.6	.02		
B4	1	5.4	.03		
C1	1	.9	.005	.9	.005
C2	1	1.8	.01	1.8	.01
C3	1	3.6	.02	3.6	.02
C4	1	5.4	.03	5.4	.03
D1	2	.9	.005		
D2	2	1.8	.01		
D3	2	3.6	.02		
D4	2	5.4	.03		
E1	2	.9	.005	.9	.005
E2	2	1.8	.01	1.8	.01
E3	2	3.6	.02	3.6	.02
E4	2	5.4	.03	5.4	.03
F1	3	.9	.005		
F2	3	1.8	.01		
F3	3	3.6	.02		
F4	3	5.4	.03		
G1	3	.9	.005	.9	.005
G2	3	1.8	.01	1.8	.01
G3	3	3.6	.02	3.6	.02
G4	3	5.4	.03	5.4	.03
H1	4				

Lot A made the best growth of any of the trees. Lots B1 and C1 made practically normal growth throughout the season. Trees in lot B2, D2, E2 and F2 varied greatly in the growth made during both seasons, but showed very little development of the brittle foliage and retained a normal luster of foliage during the summer of 1917, but the foliage became yellowish green in the season of 1918. Trees in lots B3, B4, C2, C3, D3, D4, E2, E3, F3, F4, G2, and G3, developed yellowish green foliage early in the summer of 1917 and made a very poor growth for the season. During the summer of 1918 these same trees made a fair growth, as good as during the first season, but retained a yellowish green color of foliage throughout the test. Lots C4, E4 and G4 showed a yellowish color of foliage development very early in the growing season of 1917 and did not recover from this condition throughout that season or the following. The leaves developed in each of these plots were nearly normal in size, but yellowish green in color and soon developed a brittle texture. The trees in lot H1 made a bare existence but passed through the two seasons with the loss of only one. There was no indication of mottling of color or chlorotic condition, and no development of rosette formation in the twigs of any of the trees.

ASH CONTENT OF LEAVES

Waynick (22) presented data which "indicated that the composition of a plant, as revards inorganic constituents at least may be altered enormously by variations in the surrounding solution." Keisselbach (11) found that "the per cent of ash is lower under climatic conditions having a low evaporation coefficient." Also that "the greater availability of the soil solute within certain limits, the greater was the total amount of solute taken into the plant and the smaller the amount of water used per unit of dry matter developed." He presented data which showed that the greater the amount of water used by the plant in producing a unit of dry matter the higher the per cent of ash.

The humidity of the air in the clean cultivated orchards in the irrigated sections during the summer is very low. Full data are not available, but on July 19, 1921, which was not an extremely warm or dry day, the humidity of the air in a clean tilled orchard in the Yakima Valley near Yakima, was 28 per cent; and in an adjacent orchard in which an alfalfa cover crop was growing at the same time the humidity was 46 per cent.

Leaves from rosettes and normal twigs were collected early in September, 1917, and the water soluble ash, the alkalinity of the soluble ash and the insoluble ash content determined. The results are given in Table 5. The difference in the age of the leaves of the

different lots at the time of the collection is probably the cause of the difference in the two sets. Lots 1 and 2 were collected from younger twigs than the material in lots 3 and 4. The material was all taken at the same time and it was impossible to give approximate age of the leaves. The insoluble ash is slightly higher in the normal foliage but the per cent of water soluble ash in the rosette leaves is distinctly higher than that in the normal leaves. The alkalinity of the water soluble ash is also greater in the rosette foliage.

Twigs of normal and rosetted wood were collected in September, and a microscopic study made of the starch content. The normal twigs showed a good deposit of starch throughout the length of the season's growth just finished. The rosetted twigs showed very little starch deposited at any point in the growth of the season. No chemical analysis was made, and no definite comparison is possible from such observations but a large number of twigs were examined and were so uniform in their apparent starch content that there is little room to doubt that it is representative of the conditions existing.

Table 5. The ash content of normal and rosetted foliage of apple trees.

	Tree	Total Pct. of ash	Pct. insoluble ash	Pct. water soluble ash	Alkalinity of water soluble ash
Lot 1	Normal	8.45	5.76	2.69	12.0 ccN—10 acid
Lot 2	Rosette	8.74	5.43	3.29	13.5 ccN—10 acid
Lot 3	Normal	9.72	6.95	2.77	12.5 ccN—10 acid
Lot 4	Rosette	10.53	6.70	3.83	16.7 ccN—10 acid

Normal and rosetted wood was collected in the spring and fall of 1921 from the college orchard. This material was collected from trees that were well distributed through the orchard and in many cases the rosetted and normal wood samples were collected from the same tree. This material was analyzed for total nitrogen content. The data secured are given in Tables 6 and 7. It will be noticed that the rosetted material has a much higher nitrogen content than does the normal.

Table 6. The total nitrogen content of dormant one-year-old normal and rosetted apple twigs. Each sample was composed of ten to twenty twigs and is numbered in the order collected.

	NORMAL		ROSETTE	
	Sample No.	Pct. Nit'gn	Sample No.	Pct. Nit'gn
Jonathan	21	.88	32	1.28
	38	.88	37	2.12
	44	.95	40	2.14
	46	.92	45	2.04
	47	.81	51	1.80
	57	.93	56	2.28
	62	1.02	67	2.37
	Average	.91	Average	2.01
Rome Beauty	22	.98	23	2.00
	27	.91	24	2.09
	31	1.15	26	1.80
	39	95	28	2.21
	48	.94	34	1.25
	61	.93	41	2.37
	65	.86	49	1.57
	Average	.96	Average	1.87
Wagener	30	.84	29	2.11
	60	.84	36	2.25
	62	1.06	42	2.02
	63	1.14	50	2.13
	64	.89	53	1.92
	66	1.00	55	2.19
	Average	.96	58	2.43
			59	1.79
			Average	2.10
Average of all varieties		.94		1.99

Table 7. The total nitrogen content of normal and rosetted apple foliage and wood to which the foliage was attached. The samples were composed of ten to twenty twigs each collected in late summer.

Jonathan

NORMAL				ROSETTED			
Foliage		Wood		Foliage		Wood	
Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen
7	2.33	7	1.13	5	2.42	5	2.15
15	2.22	15	.79	10	2.03	10	1.37
16	2.01	16	.61	12	2.48	12	2.24
19	1.95	19	.79	18	1.71	18	1.18
Average	2.12	Average	.83	Average	2.16	Average	1.73

Rome Beauty

NORMAL				ROSETTED			
Foliage		Wood		Foliage		Wood	
Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen	Sample No.	Pct. Nitrogen
6	2.27	6	.83	3	2.03	3	2.56
17	2.00	17	.68	8	1.66	8	1.36
20	2.18	20	.79				
11	2.32	11	.75	Average	1.84	Average	1.96
Average	2.19		.76				
Avr. both varieties	2.16		.79		2.05		1.81

HISTOLOGY

Hanson (6) has shown that the leaves in the south periphery of a tree are thicker, the palisade cells are longer and there is more intercellular space than in the leaves in the center or shaded part of the tree top. The proportions or size of the different cells and intercellular spaces in the leaves, however, are practically the same in the leaves produced in the different parts of the tree. The rosetted leaf is slightly thinner, the palisade cells are shorter and not so well developed as in the normal tissue. The open inter-cellular space between the palisade cells and the epidermis of the under side of the leaf is much greater in proportion to the thickness of the leaf in the normal than in the rosetted leaf.

In the cells in the edge of the chlorotic area of the chlorotic leaves the chloroplasts and the nuclear outlines have practically all disappeared. The cells within the chlorotic area retain their form and appear to be turgid and filled with liquid. The cell walls seem to change little in thickness but contract slightly.

The histological structure of the leaf petioles and twigs of the rosetted wood are in all respects practically normal and cannot be distinguished from those of the normal wood except by reason of difference in size of the cells. The gross morphology of the normal and affected wood is very different but the several parts seem to function normally when normal foliage is restored.

PREVENTION AND CONTROL

Pruning away the affected branches does not eliminate the trouble. Trees in which all affected wood was removed produced rosette the following season. Severe or heavy pruning of all normal wood on the entire tree does not hasten recovery. Trees in which all normal wood was removed, leaving only the affected twigs, developed water-sprouts in abundance and forced much of the affected wood into normal growth. The response was usually short-lived and the new water-sprout growth developed some rosette the second summer and the tree lost its power to respond with new growth. The affected wood recovered slowly if at all. Root pruning of affected young trees gave no improvement but tended still further to weaken the trees.

Blasting to break and pulverize the soil around the affected trees gave no permanent improvement. In a few trees a temporary improvement seemed evident, but in two or three years all evidences of improvement have usually disappeared unless cover crop or a legume crop of some kind has been planted on the land soon after the blasting was done.

Tree holes in the college orchard were opened by blasting. The charge of dynamite was placed three feet below the surface. The explosion loosened the soil above the blast and made good holes for tree planting. The trees set in these holes rosetted as badly as any of the trees set in holes opened with a spade.

The application of nitrate of soda, 300 and 500 pounds per acre, on four- and five-year-old orchards, gave no improvement in rosette condition. Dried blood used at 500 and 1000 pounds per acre made a distinct improvement in tree growth but did not cause the rosette condition to disappear. Iron sulphate applied to the soil as a top dressing at the rate of 10 pounds per tree did not modify the appearance of rosette. Gypsum, flowers of sulphur, super-phosphate, and muriate of potash, when used as fertilizer on plots in the college orchard, gave no indication of modifying the prevalence of rosette. Barnyard manure used as fertilizer gave no noticeable improvement in the rosette condition in the experimental plot. It was not used on the experimental plots in the college orchard in large enough quantities greatly to improve the physical condition of the soil. It has given slight improvement in tree development and recovery from rosette but not enough to justify its being recommended as a remedy.

A cover or shade crop of alfalfa or clover in the affected orchard has uniformly improved the orchard to such an extent that rosette has practically disappeared in five years after the cover crop has been planted. A few cases have been found in which the legume cover crop seems to be of little value but the soil in these orchards was so

extremely alkaline that the trees were evidently suffering from that cause also. The milder cases of rosette usually have been corrected within three or four years by the use of a cover crop, and an alfalfa cover crop is now generally recognized as a satisfactory remedy.

CONCLUSIONS

(1) Apple rosette is a functional or nutritional disorder of apple and pear trees. It is non-parasitic. The affected plants or parts of the plant may recover and assume normal growth.

(2) Branches badly rosetted seem to be especially subject to winter injury. Branches that have been rosetted for more than one summer very commonly bear evidence of winter injury in the discolored bark and wood.

(3) The rosette has appeared most in districts in which the humidity of the atmosphere is very low during the summer or in seasons of severe drought.

(4) The application of fertilizers and manures to the orchard soil has not been effective in correcting the soil condition or the plant food supply that causes apple rosette.

(5) Neither pruning away the affected parts of the trees nor cutting back the normal wood has permanently eliminated the trouble.

(6) Growing a legume cover or shade crop in the affected orchards during the entire summer for three or more years has uniformly been followed by a great improvement of the trees. The continuance of the cover crop for five years has practically always been accompanied by complete recovery. The first and second summer following the planting of the cover crop, the trees have usually shown indications of want of water and plant food material. Under irrigation and three years of cover crop growing, they uniformly show marked improvement.

(7) The cover crop that is left uncut on the land through the summer and is disked into the soil in the fall or the following spring seems very much more valuable to the land and trees than a cover crop handled in any other way.

(8) Alfalfa has been used with more uniform success as an orchard cover crop in the irrigated orchards of the state of Washington than any other plant and the orchards in which alfalfa has been grown as a cover crop for three years or more are practically all free of rosette.

REFERENCES

1. **Bioletti, F. T., and Bonnet, L. 1917.** Little Leaf of the Vine. Jour. Agri. Res. V. 8, pp 381-397.
2. **Brooks. Chas., and Fisher, D. F. 1918.** Irrigation Experiments on Apple Spot Disease. Jour Agri. Res. V. 12, pp 109-138.
3. **Clawson, O. T. 1916.** Rosette and Cover Crops. Better Fruit V. 10, No. 10, pp 24-25.
4. **Dauthenay, H. 1901.** Chlorosis of Fruit Trees in Calcareous Soils. Rev. Hort. 73, No. 2, pp 50-51.
5. **Floyd, B. F. 1917.** Some Cases of Injury to Citrus Trees Apparently Induced by Ground Limestone. Fla. Agri. Exp. Sta. Bul. 137.
6. **Hansen, H. C. 1917.** Leaf Structure as Related to Environment. Am. Jour. Bot. V. 5, No. 9, pp 533-560.
7. **Heald, F. D. 1920.** Non-parasitic Diseases of the Apple in Washington. 16 An. Rept. Wash. State Hort. Assoc., pp 146-158.
8. **Hilgard, E. W. 1900.** Nature, Value and Utilization of Alkali Lands. Cal. Agri. Exp. Sta. Bul. 128.
9. **Judson, L. B. ..1904.** Apple Rosette. Annual Report, Ida. Agri. Exp. Sta., pp 12-13.
10. **Kelley, W. P., and Thomas, E. E. 1920.** The Effects of Alkali on Citrus Trees. Cal. Agri. Exp. Sta. Bul. 318.
11. **Keisselbach, T. A. ..1916.** Transpiration as a Factor in Crop Production. Neb. Agri. Exp. Sta. Res. Bul. 6.
12. **Loughridge, R. H. ..1901.** Tolerance of Alkali by Various Cultures. Cal. Agri. Exp. Sta. Bul. 133.
13. **Lowther, Granville. 1914.** Apple Rosette. The Encyclopedia of Practical Horticulture. Vol. 1, pp 477-485.
14. **McMurran, S. M. 1919.** Pecan Rosette in Relation to Soil Deficiencies. U. S. D. A. Bul. 756.
15. **Mix, A. J. 1916.** Cork, Drouth Spot and Related Diseases of the Apple. N. Y. Agri. Exp. Sta. (Geneva) Bul. 426.
16. **Orton, W. A., and Rand, F. V. 1914.** Pecan Rosette. Jour. Agri. Res. V. 3, No. 2, pp 149-175.
17. **Paddock, W. 1901.** Plant Diseases. Col. Agri. Exp. Sta. Bul. 69.
18. **Rand, F. V. 1922.** Pecan Rosette, Its Histology, Cytology, and Relation to Other Chlorotic Diseases. U. S. D. A. Bul. 1038.
19. **Smith, Erwin F. ..1894.** Peach Yellows and Peach Rosette. U. S. D. A. Bul. 17.
20. **Smith, R. E., and Smith, E. H. ..1911.** California Plant Diseases. Cal. Exp. Sta. Bul. 218.
21. **Stringfellow, H. M. 1903.** Chlorosis of Trees and Vines. Texas Farm and Range. V. 22, No. 38.
22. **Waynick, Dan David. 1918.** The Chemical Composition of the Plant as Further Proof of the Close Relation Between Antagonism and Cell Permeability. Univ. Cal. Pub. Agri. Sci. V. 3, No. 8, pp 135-242.

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